Release of Microplastics from Masks

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The global panic caused by COVID-19 has continued to increase people's demand for masks. Due to inadequate management and disposal practice, these masks have entered the environment and release a large amount of microplastics (MPs), posing a serious threat to the environment and human health.

microplastics microfibers masks COVID-19

1. Introduction

With the global COVID-19 pandemic, masks have become essential personal protective equipment (PPE) for people to avoid infection by the virus. It has been proved that wearing masks can greatly prevent the rapid spread of respiratory droplets containing SARS-CoV-2 [1]. Many countries around the world, such as Germany [2], Austria [3], Israel [4], etc., enforced or still enforce mask wearing in public places. According to the prediction of a model made by the World Health Organization, it is estimated that at least 89 million medical masks and 129 billion ordinary masks are needed each month [5]. During the worst period of the epidemic, the amount of medical waste, including masks, reached 240 ton·d^{-1} in Wuhan, China. The generation of a similar amount of medical waste has been observed in Thailand, the Philippines, Malaysia, India and other places, too [6].

The use of these masks will inevitably pose a great threat to the natural environment. According to the World Wild Fund for Nature, 10 million masks per month end up in the environment, even when only 1% of masks are improperly disposed of [7]. Recent studies have also shown that 1.56 billion masks leaked into the ocean in 2020 alone, which will have unpredictable and serious effects on marine life [8]. In fact, masks have been unintentionally or accidentally disposed of in cities [9], rivers [10], coasts and beaches [11].

Masks in markets are made mainly of polypropylene, polyurethane, polyacrylonitrile, polyethylene or polyester and other polymers [12]. Among them, the most common N95 mask (which can filter 95% of air particles smaller than 0.3 μm) consists, essentially, of polystyrene [13]. These plastic-made masks can, if dumped into the environment, release microplastics (MPs) under conditions of wind, waterpower, light, etc. [14]. Due to their difficulty in degrading under environmental conditions, this released debris in the environment will likely continue to accumulate in the biosphere. It is noteworthy that mask-origin MPs are mostly fibrous and have a greater toxicity and adsorption capacity, which differs from common granular MPs [15]. Given the situation of the current serious epidemic, the released MPs will absorb nutrients in the environment and create a relatively stable microenvironment for bacteria or viruses, thereby improving the survival time and range of the latter [16]. Recent studies have shown that the longest survival time of SARS-CoV-2 on a plastic surface is 3 days. However, the virus could survive only 3 h in the air [17]. Even after 7 days, used masks could still contain infectious SARS-CoV-2 RNA [18]. Therefore, whether wasted masks and released microplastics can act as carriers of bacteria or viruses, extending their spread under wind and water flow conditions requires further research. It has been established that masks discarded by people can release heavy metals and organics into the environment [12][19], as well as adsorbing some pollutants in the environment and acting as a carrier of toxic substances [20].

So far, there have been a few reports on disposable masks exposed to the environment. They only discuss the direct negative effects of these masks on wildlife, but not the mask-origin MPs and their combined environmental toxicity over time in the environment.

2. Disposable MASKS Exposed to the Environment

As one of the greatest environmental challenges affecting human survival, plastic pollution has received global attention in recent years. Since the outbreak of the new COVID-19 epidemic in 2019, however, people's demand for mask production has increased significantly. Since masks are mainly made of plastics (the main component is polypropylene), if they are inappropriately disposed of, they can cause serious environmental problems. Assuming each person uses one mask per day, at least 5.052 billion masks need to be supplied every day in the world [21].

In the past two years alone, people could find a variety of PPE, including masks, in every corner of the world [22][23]. Up to now, the phenomenon of disposing of masks on the beach has been reported the most. In Bangladesh, 29,254 pieces of medical waste were found on one beach alone, of which 97.9% were masks [24]. In the Bushehr region of Iran, 1578 gloves were found at nine coastal sites [25]. Among them, the densely populated beaches were the most polluted. At Kwalai Beach in Kenya, one discarded mask could be found every ten square meters [26]. In addition, a large number of mask waste has been found on the beaches of Chile [27] and Morocco [28]. Incredibly, waste masks were also found on the beaches of some uninhabited islands in Hong Kong, China [29]. Chowdhury et al. [22] investigated mask-waste pollution in the coastal areas of 46 countries and found that about 150,000 to 390,000 tons of masks leaked into the ocean in 2020. Not only the marine environment is affected; plastics could be found in 76.5% of ponds in Bangladesh, most of which was floating mask waste [30]. According to an on-site study of river debris in the port of Garda, Indonesia, an unprecedented amount of PPE, including face masks, was discovered in 2020, reaching around 117 pieces per day [10]. A similar amount of mask waste was also found in Turkish cities, with an average of 182 masks per square kilometer [9]. By comparing pollution by masks in different parts of the city, it was found that the random disposal of masks in parking lots of hospitals with large population flows would be more serious [31]. What is worrying is that the demand for masks is still high, especially in developing countries. However, due to economic and managemental reasons, these areas have an insufficient capacity to deal with their mask waste. For example, Africa has become a major source of mask waste in the world; due to the lack of necessary waste management capacity, 15 out of 57 African countries have been major emitters of mask-origin plastic waste. It is estimated that masks, as much as 105,000 tons month^{-1}, are not properly handled and disposed of directly into the environment [32]. A survey performed in Poland's Silesia region shows that 42% of people disposed of mask waste mixed with household garbage [33]. It is worth noting that in many coastal countries, due to the massive use and uncontrolled disposal of masks, a large amount of mask waste will flow into the marine environment. It is found that lower-income countries and developing countries will be the major source of mask-waste emissions [22].

Like most plastic products, mask waste can float, settle or be suspended in the water body [25]. It is, therefore, expected that a large part of the mask waste is transported around the world by ocean currents, while the other part remains in the sediments on the sea floor [8]. In addition, microbial degradation and photochemical weathering can cause fragmentation and decomposition, resulting in the production of MPs. Therefore, PPE is considered a new source of secondary MP pollution in the environment that can endanger wildlife and human health [8]. Since plastic waste also promotes the spread of microorganisms and pathogens, this discarded mask waste can also be a vector of disease outbreaks [23][34].

3. Release of MPs from Masks

Plastic products can naturally decompose into tiny plastic particles. If the diameter of these particles is less than 5 mm, they are defined as MPs [35]. Compared to the pollution caused by larger plastics, MPs can more easily penetrate into the oceans [36], rivers [35], land [37] and even the atmosphere [38] because of their size and lower density. They have potential to harm ecological and human health. So far, MPs of various sizes have been found in animals and a large amount of MPs have been found in commercial products for adults [39] and even for babies [40]. Owing to their relatively stable and porous structure, these released MPs accumulate in the human body, not only through respiration but also through the food chain. Microplastics released into the environment quickly combine with some toxic substances [41] and viruses (respiratory viruses and human enteroviruses) to form a new micro-environment, which is called the plastisphere [42]. However, the release and spread of mask-origin MPs, as a secondary route of transmission of human-disease-causing viruses, e.g., COVID-19 corona viruses, do not seem to receive public attention.

As shown in **Figure 1**, the medical mask is a combination of three layers of PP-made non-woven fabric and PA-made ear ribbon, and it is easy to disperse some fiber fragments in the environment. Coupled with the effects of hydraulic scouring, mechanical wear and UV aging, the release of MPs will be faster [43][44][45][46][47]. Plastic waste generated in sanitary/medical facilities, laboratories and other contaminated sanitary/social facilities must be properly treated and disposed of in accordance with the relevant international/national regulations. In general, they must go through incineration/disinfection and then sanitary bottling or waste conversion. For example, during the lockdowns in cities, China set up mobile waste treatment stations and converted industrial waste treatment facilities into biomedical waste treatment facilities [48]. In Catalonia, medical waste has been given priority by existing incinerators [49]. However, not all countries can follow strict treatment procedures and infectious waste is often inappropriately disposed of; some developing countries (such as Thailand, the Philippines and India) dispose of PPE waste, including masks, in open landfills [50]. Studies have shown that in 2020 alone, 3.5 million tons of mask waste was landfilled worldwide. Surprisingly, these deposited masks have the potential to release 2.3×10^{21} MPs into the environment [48].

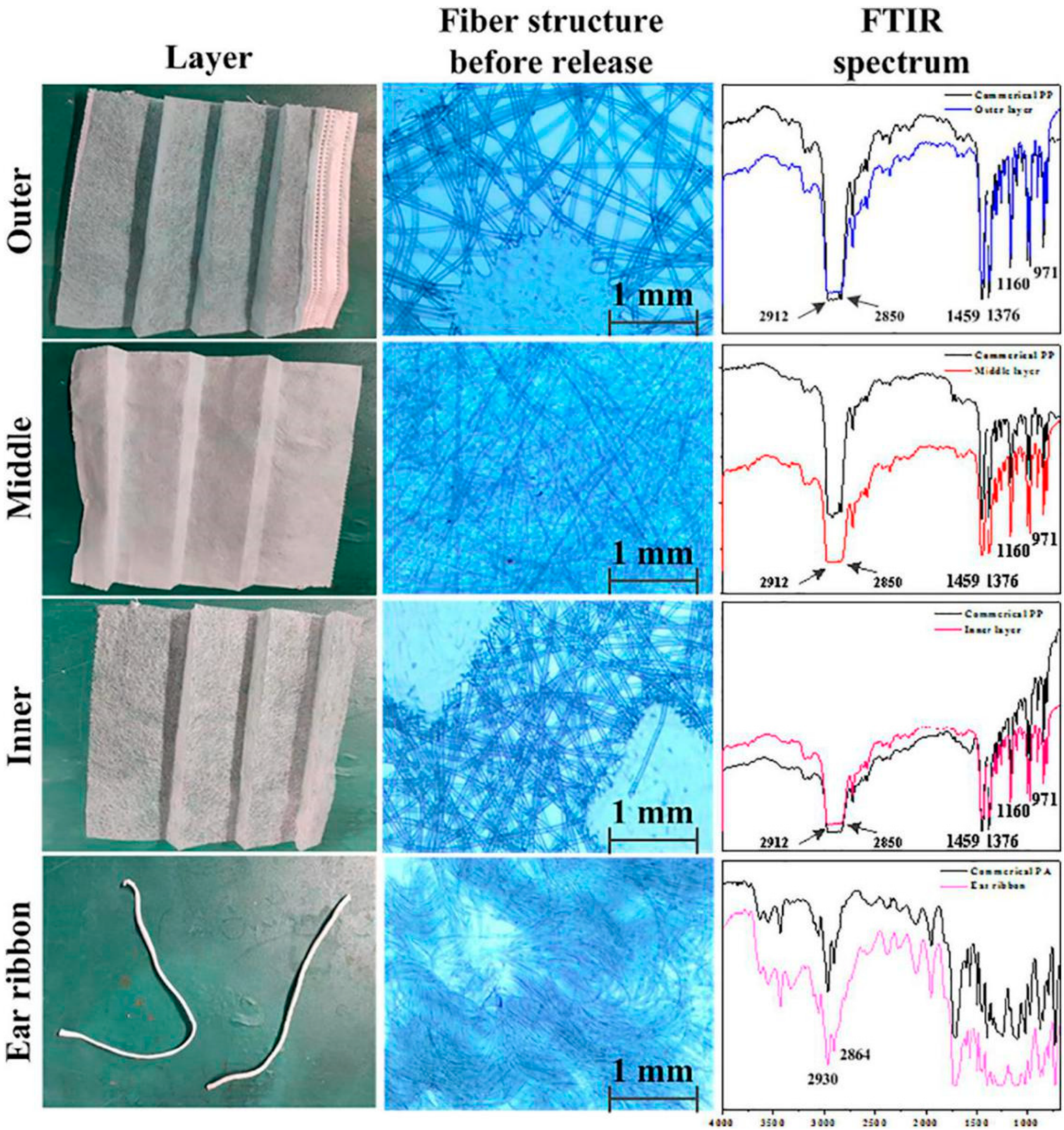

Figure 1. Structure and chemical composition of disposable surgical mask before release. Electron microscopy resolution of 3.66 μm [43].

Basically, there are different types of masks, such as N95 surgical masks, disposable surgical masks, medical masks, surgical face masks, eco-park disposable masks, etc. Together they are all made of PP or PE with three layers. Detection of MPs was confirmed using SEM, stereomicroscope and bench-top flow cytometry techniques. It was found that a minimum 1000 particles per mask/day to 1,566,560 particles per mask were released, depending on different conditions. In the water environment, a new mask may release 24,300 MPs, even in a closed glass container without the influence of wind. After three pieces of washing, 116,600 microplastics were released. When the mask is naturally aged for 2 months, it can release billions of microfibers into the aquatic environment [43]. In the marine environment, a single surgical mask can release 17,300 units of microplastic fibers in just 180 h, while a mask discarded in the ocean can completely disintegrate into microfiber fragments and aggregates within two years [46]. Masks left on the beach are washed away by sand and waves, further exacerbating the release of microplastic particles. A single mask can release more than 16 million MPs, which is more than ten times higher than the release in a purely aqueous environment [47]. In addition, there are a large number of mask products that have not undergone uniform treatment but are directly thrown away and scattered into the environment. For example, during the rainy season in Africa, masks are washed into rivers and streams through floods and ditches. In water, they are broken down into fibrous MPs, which eventually accumulate in freshwater and seawater environments [51]. Further, 42.1 MPs per liter were also found in the fish pond of the Pearl River estuary in Guangzhou, China, most of which were fibrous [52].

Laboratory experiments simulating the release of MPs from masks under wet and dry weather conditions have shown that the increase in fuzz formation in the dry environment leads to a higher release of MPs from masks. Further, the high salinity and density of seawater compared to freshwater were also found to result in the release of more MPs from masks [53]. Meanwhile, the presence of UV rays in sunlight will also affect the release of MPs in masks. As shown in **Figure 2**, UV radiation causes obvious deformation and fracture of the smooth fiber surface. If the UV radiation time is further increased, small particles attached to fibers will be produced. The increased surface roughness and fractures of the fiber surface undoubtedly enhance the ability of the mask surface to bind contaminants and the potential for the release of MPs. Akhbarizadeh et al. [25] recovered discarded PPEs from the Bushehr coast in the Persian Gulf and found that more than 10% of these waste PPEs might enter the marine environment as secondary microfibers and MP sources. With the global disease situation still serious, this will result in countless MPs entering the marine environment in the coming years, with unprecedented negative effects on fisheries and marine ecology.

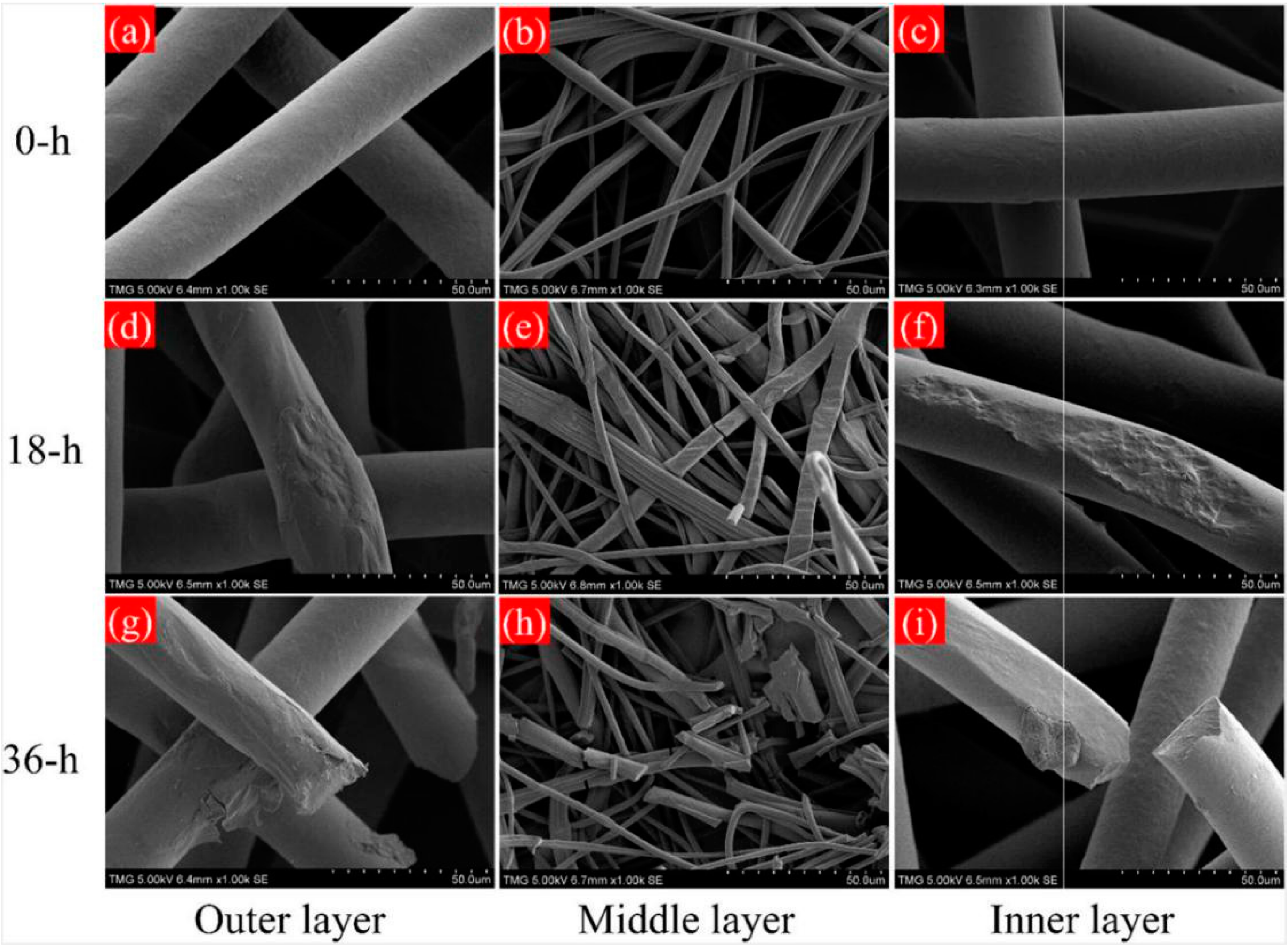

Figure 2. SEM images for the three layers of masks with different UV weathering durations: (**a**,**d**,**g**) Images at 1000 magnification of the outer layer of mask with UV irradiation for 0, 18 and 36 h (**b**,**e**,**h**). Images at 1000 magnification of the middle layer of mask with UV irradiation for 0, 18 and 36 h (**c**,**f**,**i**). Images at 1000 magnification of the inner layer of mask with UV irradiation for 0, 18 and 36 h [47].

Liang et al. [54] investigated the release kinetics of several commonly used masks under laboratory conditions and found that the rate of MPs releasing from masks gradually slowed down with time, which was well described by the Elovich release kinetic model. They also found that fibrous MPs of less than 500 μm in length were dominant in the MPs released from the masks. Due to the inevitable exposure to radiation and material wear for the used masks, the production and release of MPs are further promoted. Studies have shown that the amount of MPs released from a used mask is 6.0–8.1-times higher than those from a new mask [51]. During the wearing process, people inevitably breathe in fibrous MPs. Li et al. [44] conducted an investigation into the inhalation risk of MPs using seven popular masks on the market. The results show that both N95 masks and medical surgical masks release fibrous MPs into the air, bringing about a higher risk of MPs inhalation for humans. Even reusable masks can release 124 to 308 mg of microfiber per kilogram during the washing process, which corresponds to 640,000 to 1,500,000 microfibers [55]. Therefore, it can be said that, regardless of mask type, a large amount of fibrous MPs is released. The size of these MPs is known to be between 5 nm and 600 μm; most of the MPs are <1 μm [56]. Using flow cytometry, Mogana et al. (2021) analyzed the size of MPs released from submicron masks and found it was 0.1–0.5 μm [45]. Microplastics of this size are easily ingested by aquatic organisms to enter the food chain. Therefore, there is an urgent need for action to prevent mask waste from entering the environment.

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